

WHAT IS CLAIMED IS:

1 1. A video-based animal behavior analysis system, comprising:
2 a computer configured to determine a position and shape of an animal from
3 video images and characterize activity of said animal based on analysis of
4 changes in said position and said shape over time.

1 2. The system of claim 1, further comprising:
2 a video camera and a video digitization unit coupled to said computer for
3 capturing said video images and converting said video images from analog to
4 digital format.

1 3. The system of claim 2, further comprising:
1 an animal identification, segregation, and tracking module receiving
2 said video images.
3

1 4. The system of claim 3, wherein said computer further includes a
2 behavior identification module for characterizing activity of said animal, said
3 behavior identification module being coupled to said animal identification,
4 segregation, and tracking module.

1 5. The system of claim 4, wherein said computer further includes a
2 standard animal behavior storage module that stores information about known

3 behavior of a predetermined standard animal for comparing the activity of said
4 animal, said standard animal behavior storage module being coupled to said
5 behavior identification module.

1 6. The system of claim 1, wherein said animal is a mouse.

1 7. The system of claim 1, wherein said animal is a rat.

1 8. A method of determining and characterizing activity of an animal
2 using computer processing of video images, comprising the steps of:
3 detecting an animal in said video images;
4 tracking changes to said animal over a plurality of said video images;
5 identifying and classifying said changes to said animal; and
6 characterizing said activity of said animal based on comparison to pre-trained
7 models or rules of such activity.

1 9. The method of claim 8, wherein said step of characterizing said
2 activity includes the steps of:
3 describing a sequence of postures as behavior primitives; and
4 aggregating behavior primitives into actual behavior over a range of images;

1 10. The method of claim 9, wherein said step of characterizing said
2 activity by describing and aggregating behavior primitives further includes the
3 steps of:

4 describing a set of conditions and rules required for characterizing said
5 activities; and
6 matching and testing generated features to see if said conditions and rules are
7 satisfied;

1 11. The method of claim 8, wherein said detecting an animal includes
2 using a background subtraction method comprising the steps of:
3 apply a lenient threshold on a difference between a current image and a
4 background so as to determine a broad region of interest;
5 classify by intensity values various pixels in said region of interest to obtain
6 said animal, by selecting only those intensity values that belong to the set of
7 model intensity values of the animal; and
8 refine contours of said animal image by smoothing.

1 12. The method of claim 10, wherein said posture determination and
2 description includes using statistical and contour-based shape information.

1 13. The method of claim 12, wherein said step of identifying and
2 classifying changes to said animal includes using statistical shape information
3 selected from the group consisting of:
4 area of the animal;
5 centroid position of the animal;
6 bounding box and its aspect ratio of the animal;
7 eccentricity of the animal; and

8 a directional orientation of the animal relative to an axis as generated with a
9 Principal Component Analysis.

1 14. The method of claim 12, wherein said step of identifying and
2 classifying changes to said animal uses contour-based shape information
3 selected from the group consisting of curvature measures, thickness measures,
4 relative orientation measures, length measures, and corner points.

1 15. The method of claim 12, wherein said step of identifying and
2 classifying changes to said animal includes identifying a set of model postures
3 and their description information, said set of model postures including
4 horizontal side view posture, vertical posture, cuddled posture, horizontal
5 front/back view posture, partially reared posture, stretched posture, hang
6 vertical posture, hang cuddled posture, eating posture, or drinking posture.

1 16. The method of claim 15, wherein said step of identifying and
2 classifying changes to said animal includes classifying the statistical and
3 contour-based shape information from a current image to assign a best-
4 matched posture.

1 17. The method of claim 10, wherein the said step of describing said
2 behavior primitives includes the step of identifying patterns of postures over a
3 sequence of images.

1 18. The method of claim 17, wherein said step of describing said behavior
 2 primitives step further includes the step of analyzing temporal information
 3 selected from the group consisting of direction and magnitude of movement of
 4 the centroid, increase and decrease of the eccentricity, increase and decrease of
 5 the area, increase and decrease of the aspect ratio of the bounding box, and
 6 change in contour information.

1 19. The method of claim 10, wherein the said step of determining actual
 2 behavior by aggregating behavior primitives includes the step of analyzing
 3 temporal ordering of the primitives, such as using information about a
 4 transition from a previous behavior primitive to a next behavior primitive, and
 5 applying all applicable conditions and rules.

1 20. The method of claim 19, wherein said temporal analysis is a time-
 2 series analysis such as Hidden Markov Model (HMMs).

1 21. The method of claim 19, wherein the said step of determining actual
 2 behavior includes identifying actual behavior selected from a group of pre-
 3 trained behavior models.

1 22. The method of claim 21, wherein said group of behavior models
 2 includes the behavior of rearing up to a fully reared up or partially reared up
 3 position, and said rearing behavior is determined by the sequence of posture
 4 starting from cuddled, horizontal side-view, or horizontal front/back view

5 postures to ending in a vertical or partially reared posture;

1 23. The method of claim 21, wherein said group of behavior models
2 includes the behavior of coming down from a reared up or partially reared up
3 position, and said come down behavior is determined by the sequence of
4 postures starting from vertical or partially reared postures to ending in a
5 cuddled, horizontal side view or horizontal front/back view posture;

1 24. The method of claim 21, wherein said group of behavior models
2 includes the behavior of eating, and said eating behavior is determined by a
3 sequence of eating postures where the mouth of the animal is in touch with a
4 food container;

1 25. The method of claim 21, wherein said group of behavior models
2 includes the behavior of drinking, and said drinking behavior is determined by
3 a sequence of drinking postures where the mouth of the animal is in touch with
4 a water spout;

1 26. The method of claim 21, wherein said group of behavior models
2 includes the behavior of digging, and said digging behavior is determined by
3 the aft movement of bedding by the animal with its fore and hind limbs;

1 27. The method of claim 21, wherein said group of behavior models
2 includes the behavior of foraging, and said foraging behavior is determined by

3 the movement of bedding using the mouth and forelimbs;

1 28. The method of claim 21, wherein said group of behavior models
2 includes the behavior of jumping, and said jumping behavior is determined by
3 a single up and down movement of the animal;

1 29. The method of claim 21, wherein said group of behavior models
2 includes the behavior of jumping repetitively and said repetitive jumping
3 behavior is determined by several continuous up and down movement of the
4 animal;

1 30. The method of claim 21, wherein said group of behavior models
2 includes the behavior of sniffing, and said sniffing behavior is determined by
3 random brisk movement of the head while the rest of the body remains
4 stationary;

1 31. The method of claim 21, wherein said group of behavior models
2 includes the behavior of hanging from the top of the cage, and said hanging
3 behavior is determined by a sequence of postures starting from vertical posture
4 to ending in a hang vertical or hang cuddled posture;

1 32. The method of claim 21, wherein said group of behavior models
2 includes the behavior of landing after hanging, and said landing behavior is
3 determined by a sequence of postures starting from a hang vertical or hang

4 cuddled posture to ending in a vertical posture;

1 33. The method of claim 21, wherein said group of behavior models
2 includes the behavior of sleeping, and said sleeping behavior is determined by
3 the absence of major movements of the contour of the animal for a prolonged
4 period of time;

1 34. The method of claim 21, wherein said group of behavior models
2 includes the behavior of twitching during sleep, and said twitch behavior is
3 determined by the detection of a brief period of substantial movement and the
4 resumption of sleep activity;

1 35. The method of claim 21, wherein said group of behavior models
2 includes the behavior of awakening from sleep, and said awaken behavior is
3 determined by a prolonged movement of the animal after sleep has set in;

1 36. The method of claim 21, wherein said group of behavior models
2 includes the behavior of grooming, and said grooming behavior determined by
3 brisk movement of limbs and mouth in a cyclical and periodic pattern;

1 37. The method of claim 21, wherein said group of behavior models
2 includes the behavior of pausing briefly, and said pause behavior is
3 determined by brief absence of movement of the animal;

1 38. The method of claim 21, wherein said group of behavior models
2 includes the behavior of urinating, and said urinate behavior is determined by
3 the detection of the tail being raised up and the animal remaining stationary
4 briefly;

1 39. The method of claim 21, wherein said group of behavior models
2 includes the behavior of turning, and said turn behavior is determined by a
3 sequence of postures starting from horizontal side view or cuddled posture to
4 ending in a horizontal front/back view posture, and vice versa;

1 40. The method of claim 21, wherein said group of behavior models
2 includes the behavior of circling, and said circling behavior is determined by a
3 3 or more successive turns;

1 41. The method of claim 21, wherein said group of behavior models
2 includes the behavior of walking or running, and said walking or running
3 behavior is determined by the continuous sideways movement of the centroid
4 of the animal;

1 42. The method of claim 21, wherein said group of behavior models
2 includes the behavior of stretching its body vertically or horizontally, and said
3 stretch behavior is determined by a concave shape of the animal's back;

1 43. The method of claim 21, wherein said group of behavior models

2 includes the behavior of chewing, and said chewing behavior is determined by
3 the movement of the mouth while the mouth is not in touch with a food
4 container;

1 44. The method of claim 21, wherein said group of behavior models
2 includes the behavior of remaining stationary, and said stationary behavior is
3 determined by the animal remaining in the same place and not performing any
4 of the other behaviors;

1 45. The method of claim 21, wherein if the activity cannot be characterized
2 by any of the behavior models, the behavior is deemed to be unknown;

1 46. The method of claim 8, wherein said steps are also performed in night
2 conditions by using red light to simulate such night conditions, or by using
3 infra-red cameras to capture the images with no light;

1 47. The method of claim 8, wherein said steps are also performed with a
2 plurality of cages or arenas, each of which contains a single animal;

1 48. The method of claim 8, wherein said step of detecting animal includes
2 the step of detecting body parts of the animal;

1 49. The method of claim 48, wherein said body parts include the head;

1 50. The method of claim 48, wherein said body parts include the tail;

1 51. The method of claim 48, wherein said body parts include the ear;

1 52. The method of claim 48, wherein said body parts include the upper and
2 lower back;

1 53. The method of claim 48, wherein said body parts include the abdomen;

1 54. The method of claim 48, wherein said body parts include the hind-
2 limbs;

1 55. The method of claim 48, wherein said body parts include the
2 forelimbs;